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Comparative study on community structural diversity of pests in pomelo orchard with different management modes

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In order to learn the community structural diversity of pests and temporal dynamics in different management modes of pomelo orchard, we selected abandoned pomelo orchard (AM) and traditional pomelo orchard (TM) to investigate the characteristics of pest community structure by netting, observation and sticky board trapping methods and classified and identified through the methods of morphology and molecular biology from May to October in 2020. The results showed that the amount of species was larger in AM orchard, while the individuals of pests were less than those in the TM orchard.The values of *Margalef's index*, *Shannon-wiener index and Pielou index* were all showed bigger in TM than those in AM, while the *Simpson index* was smaller, all of which with significant differences (P<0.05). The absolute advantage insects were *Dacus dorsalis* (19.75%), *Dialeurodes citri* (13.28%) and *Lucilia sericata* (10.15%) in TM orchard and *Dacus dorsalis* (75.87%) and *Rhynchocoris humeralis* (14.51%) in AM orchard. There was significant difference between the two community relative stability indexes (P<0.05). The similarity index of insect communities in both orchards was in the range of 0.18 to 0.40, which indicated moderately dissimilar to extremely dissimilar. The richness, diversity and evenness of insect community in TM orchard were bigger than those in AM orchard, which demonstrated that the ecological environment was more stable with more reasonable insect community structure and less particularly advantageous pest occurrences. This also indicated that it is important to utilize scientific management measures to create a harmonious and stable ecological environment, maintain appropriate diversity of ground cover plants, avoid abuse of chemical pesticides, build pest populations at reasonable thresholds and achieve the goal of improving quality of fruits and increasing income for planters.
Keywords: Vegetation, Pests, community structure, diversity, ecological control.

INTRODUCTION

Insects are the largest group of terrestrial organisms and are more sensitive to changes in habitats such as regional ecological environment, vegetation evolution, and artificial disturbances than other species; Kitching *et al*., 2023). Their species and quantity are often used as important criteria for evaluating environmental characteristics and quality. The diversity of insect communities is directly related to the condition of the entire ecosystem, and insect communities in healthy ecological environments usually have high diversity (Shull *et al*., 2019; Adams *et al*., 2020. In farmland ecosystems, agricultural cultivation management can affect the distribution, species, quantity, and population density ratio of various biological populations (Faucon *et al*., 2017; Liang *et al*., 2022; Akbar et al., 2023). If there is a significant loss of biodiversity in farmland, the community structure, species richness, abundance, and dimensions will also change (Liu *et al*., 2022). Plant Species diversity is an important part of biodiversity and plays an important role in providing ecosystem services (Soliveres *et al*., 2016; Yang *et al*., 2022). Protecting plant diversity in agricultural ecosystems through scientific management measures has an impact on the diversity and quantity of herbivorous insects (Atakan and Pehlivan, 2015; their predatory and parasitic natural enemies (Muiruri *et al*., 2019; Martini *et al*., 2022). Many researchers have made significant progress in exploring the characteristics of regional insect communities and their relationship with biodiversity (Setzer and Vanhala, 2019)

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laying the foundation for ecological monitoring and pest ecological management. (Mukhtar & Mohamad, 2022).
In this study, we selected two pomelo orchards in different habitats with different management modes to investigate the diversity of pests and compared the differences in insect population, quantity, community stability, biological diversity index and community similarity between the two orchards.

MATERIALS AND METHODS

***Overview of Test Site*:** The study area was located in the planting base of Sha Tin pomelo in Meixian District, Meizhou City, Guangdong Province, China. Two artificial pomelo orchards with different management modes and natural habitats were selected in this experiment. The area of each orchard is greater than 1.33 hm^2 and the average tree age is 15-20 years. The abandoned mode (AM, the same below) orchard, which had been abandoned for 3 years, was located in Song Yuan Town, with a few shrubs and tall trees in the orchard, minolity of understory of herbs, and vegetation coverage rate of about 65%, without fertilization and pest control. The traditional mode (TM, the same below) orchard was located in Songkou town. There were varieties of undergrowth weed species, shrubs, predominantly herbaceous plants. The vegetation coverage rate reached around 85%. Weeds were controlled by herbicide or chlormequat at a height of 20-60 cm above the ground. Fertilizer and pest control were applied normally during the planting period.
***Test Methods*:** Five sample plots with similar habitats were randomly selected in each of the two study areas, and two trees were selected in each sample plot. The insect resources in the experimental area were investigated by Martensian net, sweeping net, direct observation and sticky board trapping methods. Martensian net trapping method: Chossing five points randomly in the orchards, setting up a Martensian net in a relatively open plot beside the pomelo tree for trapping, gathering the insects in bottles with alcohol solution. Sweeping net: Sweeping randomly 20 times within each sample site by using insect trapping nets with 80 mesh. Direct observation: Directly observing and recording the species and number of insects in the sample area with eyes when sweeping the net to collect insects. Sticky board trapping: Selecting one tree in each sample area, and hanging yellow sticky boards on branches 1.6m above the ground in four direction of east, west, south and north of each tree, which were mainly used to trap *Dacus dorsalis* and other insects of Dipteran. Insect collection on fruit tree canopy: Randomly selecting three leaves of a branch from the lower and middle of the tree in four directions of east, west, south and north, with the branch back to the room for classification and identification. The survey was conducted from May to October in 2020, postponed if it rains, sampling every 15 days, total 10 surveys throughout the year. The collected insect specimens were put into gathering bottles, triangular paper bags or treated poison bottles, marked and brought back to the laboratory for classification and identification.
***Specimen processing and morphological identification of insects*:** The collected insect samples were taken back to the laboratory for specimen preparation, identification, and classification. Insect identification mainly involved observing the morphological characteristics of insects under an optical microscope,and identifying them based on insect's classification Atlas. For species difficult to identify, DNA extraction was used for identification.
***Molecular biological identification of insects*:** For difficult insect species, the identification of insect species was carried out with the help of DNA barcoding (including macro barcoding) technology. The animal tissue genome DNA extraction kit was used to extract the insect genome according to the kit instructions, and 2μL DNA was taken to use as a template for PCR amplification and electrophoresis using COI gene specific primers (Table 1). The PCR products were sent to Qingke Biotechnology Co., Ltd. for sequencing, and the obtained nucleotide sequences were subjected to Blast alignment in NCBI.

Table 1. PCR primer design.

Amplification region	Primer name	Primer sequence (5'-3')
COI	LEPF1	ATTCAACMAATCATAAAGATATKG
	LEPR1	TAAACTTCTGGATGTCCAAAAAATCA

***Data processing*:** *Diversity index characteristics*
***Margalef's richness index (E)*:** $E = \frac{S-1}{lnN}$
***Shannon-Wiener diversity index (H')*:** $H' = \sum_{i=1}^{S} PilnPi$
***Pielou evenness index (J)*:** $J = \frac{H'}{ln\,S}$
***Simpson dominance index (C)*:** $C = \sum_{i=1}^{S} \frac{Ni(Ni-1)}{N(N-1)}$
***Community relative stability index (I)*:** I= S / N
In the formulas above, Pi is the relative abundance of the i-th species. Ni is the number of individuals in the i-th species. S is the number of species in the community. N is the total number of individuals of all species in the community (Pan *et al*., 2020; Malvandi *et al*., 2021; Zou *et al*., 2022).
***Criterion for the dominant insect community*:** The proportion of individuals of a certain type of insect corresponding to the dominant taxon is >10%, that to the common taxon is 1% to 10% and the rare taxon is <1% (Coelho *et al*., 2020).
***Similarity index of insect communities*:** Similarity index of insect communities was analyzed by using Jaccard's similarity coefficient (J). The formula is as follows: J = c/ (a + b) - c, (a is the number of insect species in habitat of type A, b is the number of insect species in habitat of type B, and c is the number of insect species in both habitats of types A and B).

According to the principle of Jaccard similarity coefficient, when J is 0-0.25, it is extremely dissimilar. when J is 0.25-0.50, it is moderately dissimilar. when J is 0.50-0.75, it is moderately similar. When J is 0.75-1.00, it is extremely similar (Liu *et al*., 2010).

RESULTS AND DISCUSSION

Insect community structure and composition in orchards under AM and TM**:** A total of 6,043 insect specimens were collected in this study. The number of species in AM orchard was 43 and the number of individuals was 3,431. The number of species in TM orchard was 48 and the number of individuals was 2,612. To facilitate statistical description, specimens of Arachnida (Ixodes) were tentatively included in the insect specimens for statistical purposes. The collected insects belonged to 7 orders, 35 families, 65 species, of which 6 orders, 28 families and 43 species in AM orchard and 6 orders, 26 families and 48 species in TM orchard. The top three most amounts of insects collected were orders of Diptera (78.37%), Hemipter (18.19%) and Lepidoptera (2.42%) in AM orchard, with the same orders of Diptera (40.62%), Hemipter (28.60%) and Lepidoptera (22.36%) in TM orchard. In terms of the number of insect species collected, the top three with the largest number were Lepidoptera (18), Hemipter (15) and Diptera (4) in AM orchard while Lepidoptera (20), Hemipter (14) and Orthoptera (6) in TM. It was found by further analysis that among the investigated insects, stinkbug and aphids of Hemiptera, flies of Diptera,as well as moths of Lepidoptera were common groups, while insects of Coleoptera, Orthoptera and Hymenoptera were rare groups, and the number of population was small in pomelo orchards in both management modes (Tab.2). In the TM orchard, there were 13 species of insects whose individual number accounted for more than 1%. In addition to three absolute advantage insects of Dacus dorsalis (19.75%), Dialeurodes citri (13.28%) and Lucilia sericata (10.15%), the others were Aphidoidea (9.19%), Lucilia cuprina (7.54%), and Panonchus citri (5.74%). The remaining species accounted for 1% to 4%. In the AM orchard, there were only four species accounting for more than 1%, two of which were absolute advantage insects of Dacus dorsalis (75.87%) and Rhynchocoris humeralis (14.51%), the remaining two species were Dialeurodes citri (1.34%) and Empoasca flavescens (1.17%).

The total numbers of insects in TM were more than in AM, while species numbers were less than in AM, which increased from May to the end of August when peaked at 26, then decreased to the end of October with a minimum of 8. The number of species in artificial orchards remained relatively flat in the first month and a half, ranging from 25 to 35, with slight fluctuations. After September 15th, it decreased rapidly, reaching a minimum of 9. The insect's numbers in AM orchard. The number of insects in AM orchard had been increasing from May to the end of September, reaching a peak of 534 and then beginning to decline. On the other hand, the numbers of insects in TM orchard showed a more significant fluctuation, reaching a peak of 403 in Junes and the lowest value in August of 154, and it began to decline again after rising in late September (Fig. 1).

There were differences in the dominant insect taxa between these two orchards, in which the dominant insect populations in AM orchard were Diptera and Hemiptera, while in TM orchard were Diptera, Hemiptera and Lepidoptera (Table 2). In AM orchard, Dacus dorsalis of Diptera accounted for the largest number of overall insects with 75.87%, which kept increasing from 30th May to 30th September, peaked at 432 then declined. The other insect followed was *Rhynchocoris humeralis* of Hemiptera with 14.51%, which almost changed the same with Dacus dorsalis, which peaked at 30th September with 81. In TM orchard, *Dacus dorsalis* and *Lucilia sericata* of Diptera, *Dialeurodes citri* of Hemiptera were more advantageous insects, with respective proportions in order of 19.75%, 13.28% and 10.15%. *Dacus dorsalis* maintained an upward trend in the first two months and reached its peak in mid-July, with relatively gentle changes until the end. The variation of *Lucilia sericata* fluctuated greatly, rising from May with 2 to July 30th, decreasing in the following two months, and then starting to rise, reaching its maximum at the end of October with 70. The occurrence of *Dialeurodes citri* was intermittent, with a certain number from May to 15th June, 30th July, as well as from 15th September to 15th October (Fig. 2).

Table 2. Composition of insect community in orchards under TM and AM.

Insect	Species numbers		Insects numbers		Relative abundance (%)	
	AM	TM	AM	TM	AM	TM
Orthoptera	3	6	17	49	0.50	1.88
Hemipter	15	14	624	747	18.19	28.60
Lepidoptera	18	20	83	584	2.42	22.36
Coleoptera	2	3	16	21	0.47	0.80
Hymenoptera	1	0	2	0	0.06	0.00
Diptera	4	4	2689	1061	78.37	40.62
Acari	0	1	0	150	0.00	5.74
Total	43	48	3431	2612	100.00	100.00

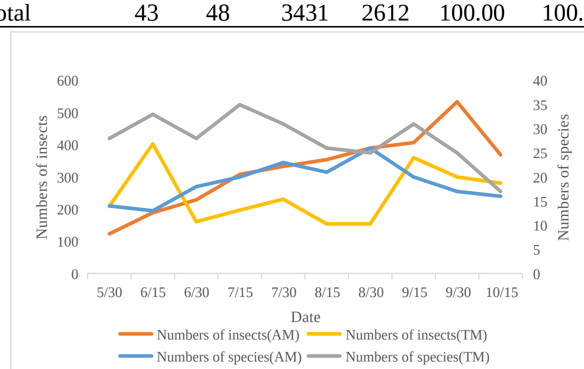


Figure 1. Changes of the numbers of species and insects in two orchards under TM and AM.

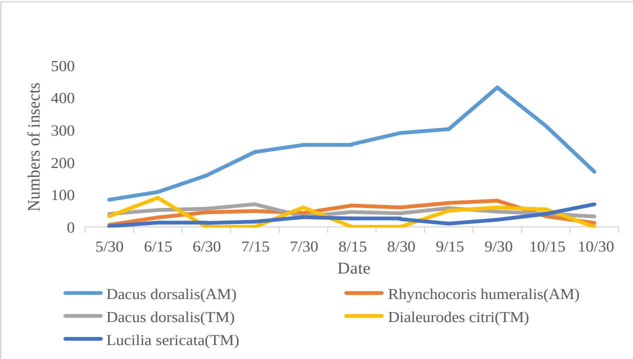


Figure 2. Changes of numbers of dominant insects in two orchards under TM and AM.

***Comparison of characteristic values of insect communities in orchards under AM and TM*:** The diversity index of the collected insect community was counted according to the different dates of the orchards with different management modes. It could be seen that the amounts of insect species and insects were smaller in AM orchard than in TM orchard while the number of insects was bigger, both with significant differences. Margelaf index, Shannon index and Pielou index in TM orchard were significantly larger than those in AM, while Simpson index was smaller, which indicated that the number of insects and the diversity of species were more in TM orchard, where the species distribution was also more uniform in the community naturally drawing a conclusion that the stability of insect community and the ecosystem were stronger in TM orchard than in AM (Table 3).

Table 3. Characteristic values of insect communities in orchards under AM and TM.

	Orchards	
	AM	TM
Species numbers	17.82±1.51b	26.18±2.26a
Insects numbers	311.91±35.8a	237.45±26.3a
Margelaf index	2.95±0.24b	4.64±0.41a
Shannon index	0.97±0.07b	2.33±0.08a
Pielou index	0.34±0.03b	0.73±0.01a
Simpson index	0.59±0.03a	0.15±0.01b
I	0.07±0.01b	0.12±0.01a

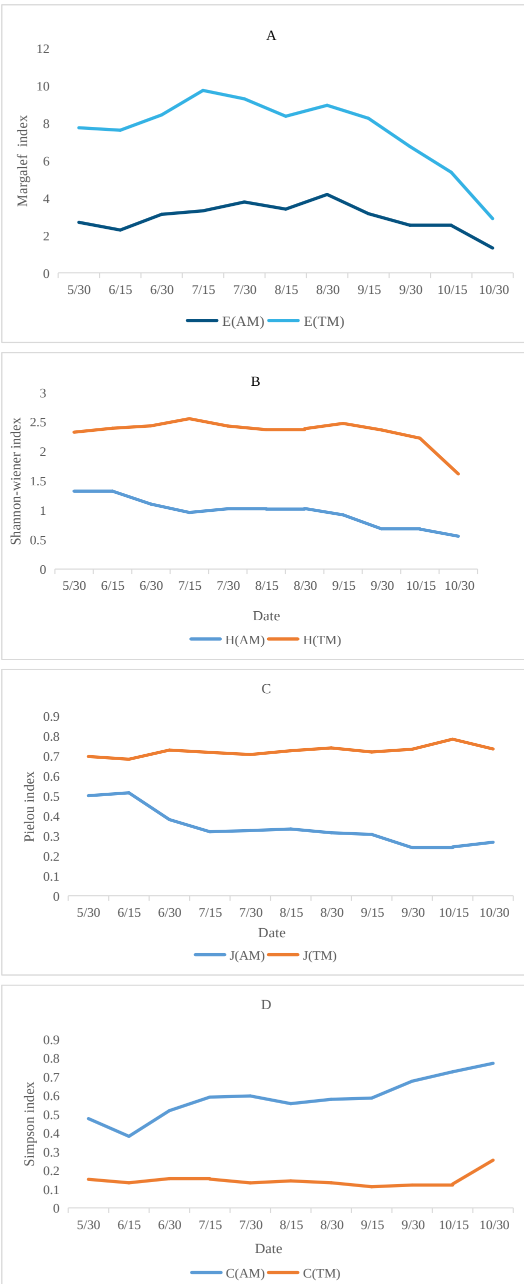
Notes: The data in the same column marked with different lowercase letters indicated significant difference ($P < 0.05$).

Margelaf index, showing the species richness, was generally higher in TM orchard than that in AM, with a significant difference. From May to June, the Margalef indexes of both orchards were increasing, and the highest value of TM orchard appeared around July 15th, reaching 6.44, before gradually decreasing to the lowest at 1.57 on October 30th. The highest index AM orchard was at the end of August, at 4.19, and subsequently began to decline to 1.33 until the end of the investigation time (Fig. 3 A). It was mainly due to the fact that the reproduction amounts of insects reproducing were more and more because of the suitable temperature, vibrant habitat and adequate nutrients during the period from June to August. There was significant difference in Shnnon-wiener index between AM and TM orchard, which indicated that the insect species in AM orchard were much more diverse than those in TM. The former grew to its highest value in June and began to show a downward trend. However, the latter reached its maximum value around July 15th and then began to slowly decline, both reaching their minimum values at the end of October, which was 1.62 and 0.56 respectively. In general, the temporal fluctuations of the former were bigger than those of the latter (Fig. 3 B), probably because the rampant growth of plants and rapidly increasing dominant insect populations in the habitat had suppressed the growth of some insect populations in AM orchard, while the habitat changes and nutrient supply in the TM orchard were relatively stable, and the diversity changes of insects were more gentle, leading to the difference between the two orchards.

Pielou index, which illustrated the uniformity of the insect community, was significantly greater in TM orchard than that in AM, which showed that the distribution and quantity of species were more uniform. Obviously, there was a slight change in TM orchard, which was to maintain a higher value from 0.69 on June 15th to 0.79 on October 15th, while a more intense fluctuation in AM orchard from 0.24 on September 30th to 0.52 on June 15th (Fig.3 C). On the other hand, Simpson index and Pielou index of insects showed an opposite trend, where the dominance of TM should be much smaller than that of AM. Actually, it was indeed like this. This data in TM changed slightly from May to October 15th around 0.13 to 0.15, with a high value of 0.26 at the end of October. Meanwhile,the lowest point of 0.38 in AM orchard appeared on June 15th and then continued to grow until the highest point of 0.77 on October 30th (Fig.3 D). The reason for this might be the insect species ascended followed by factors such as a increasing temperature and ripening fruits in AM orchard without any interference, bringing about a sharp increase in the population of dominant pests such as *Dacus dorsalis* and *Rhynchocoris humeralis* that crowded out the Lebensraum of other insect species, and the evenness drops rapidly.From another perspective, it might also be related to constant anthropogenic disturbances, such as regular chemical control and moderate weeding in TM orchard, resulting in a relatively stable biological community.

The similarity index of insect communities in both orchards was in the range of 0.18 to 0.40. The highest level of similarity occurred on May 30th, followed by a rapid decline and continued to fluctuate. Then it came to the minimun of 0.19 on October 15th, after which went up with a certain degree till October 30th (Fig. 4). Perhaps it was because at the very

beginning of the stage when the number of species in the habitat began to increase, the biological species, phenological period, nutrient supply, fruit maturity, human intervention etc. in two habitats were relatively similar, so the species, population density and community characteristics of insects were moderately dissimilar. As the stability of the ecosystem within the habitat was disrupted, the diversity dynamics of insects changed accordingly, which caused great dissimilar then.



Notes: A: Margelaf index, B: Shannon-wiener index, C: Pielou index, D: Simpson index

Figure 3. Characteristics of diversity index of insect community in orchards under AM and TM.

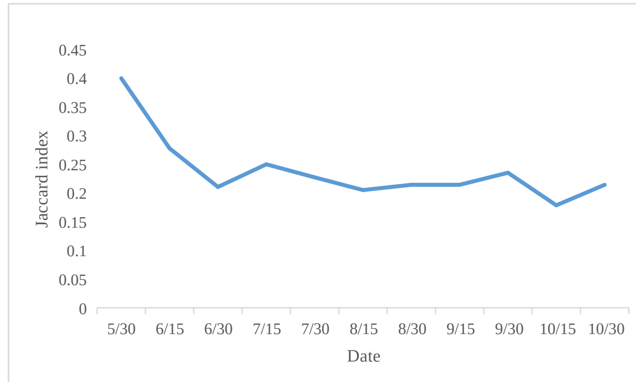


Figure 4. Insect community similarity index in orchards under AM and TM.

DISCUSSION

Most of the insects in the orchard belong to small and medium-sized insects, which are easy to collect and have sensitive responses to habitat structure and environmental changes (Fumy *et al.*, 2020; Uhl *et al.*, 2020), and are excellent Model organism for studying the impact of environmental changes (Poniatowski *et al.*, 2018; Löffler *et al.*, 2019; Theron *et al.*, 2022). Studies on the local scale have found that habitat quality is the most important factor affecting insect diversity (Marini *et al.*, 2009; Preuss *et al.*, 2011), and habitat quality is determined by the combination of complex and usually interrelated vegetation structure (Poniatowski and Fartmann, 2008; Marini *et al.*, 2009; Preuss *et al.*, 2011; Poniatowski *et al.*, 2018; Löffler *et al.*, 2019) and Microclimate (Mahmood *et al.*, 2018). In this study,we investigated and analyzed the species composition and community diversity of pests in different habitats of pomelo orchards under two management modes (AM&TM). A total of 10 investigations were conducted, and 6,043 insect were collected, belonging to 7 orders and 43 families. Most insects collected were orders of Diptera, Hemipter and Lepidoptera, with dominant pests of *Dacus dorsalis* (19.75%) and *Dialeurodes citri* (13.28%) in TM orchard, *Dacus dorsalis* (75.87%) and *Rhynchocoris humeralis* (14.51%) in AM orchard, showing that the composition of insect species in the same region was similar, which resulted from suitable environmental temperature and water source environment for the growth and development of insects (Wang *et al.*, 2021). However, the amounts of advantageous pests in AM orchard was more extremely higher than another one, it probably was relative to the poor ecosystem formed by single species type in the habitat there and a harmonious ecological environment created by human intervention on daily management. This

confirms that the community stability of TM orchard is significantly greater than that of AM orchard (P<0.05).

Increased ground vegetation density at both field and landscape scales favours more diverse and abundant insect communities (Bosco *et al*., 2023). The species richness can most intuitively compare the species diversity of insect communities in different habitats, and the more biological species, the greater the species richness index (Zhao *et al*., 2020). In our research, we found that, comparing to AM orchard, TM orchard had a richer variety of plant species, denser ground cover plants, and significantly higher abundance and diversity of pests, where community composition and insect population diversity were different, with more amounts of species and less individuals, higher values of *Margalef index, Shannon-wiener index, Pielou index* and lower *Simpson index* in TM orchard than in AM orchard, which may be due to the rich species of ground cover plants in TM orchard, the relatively stable ecosystem, and the complex ecosystem structure, providing a better habitat for insects to feed and reproduce. In addition, TM orchard belongs to grassland habitat, and its insect community species richness, community diversity index and community evenness index there were higher than those of AM orchard with low grass area. That's why there were many insects of Orthoptera in TM orchard, such as *Locusta migratoria manilensis*, *Oxya chinensist*, *Oxya agavisa, Holochlora sp.* during the investigating process. The lower quantity of individuals and *Simpson index* in TM orchard might owed to a relatively stable insect ecosystem with biological species of a large variety and quantity formed by regular but not excessive manual intervention measures, such as necessary targeted chemical control, reasonable weeds control measures, sufficient water and fertilizer supply, and diversified plant nutrition supply. Another reason was the lack of effective suppression mechanisms after the outbreak of dominant pests (*Dacus dorsalis*, *Rhynchocoris humeralis*) that squeezed the survival space of other insects and inhibited the development of other insect populations in AM orchard.

The species similarity coefficient of insect communities reflects the degree of similarity among different habitats. In this study, the species similarity coefficient of insect communities in TM and AM habitats was the highest at 0.4, and the species of insect communities between habitats showed moderate dissimilarity. From June 15th until the end of the investigation, the coefficient value remained between 0.18 and 0.25, and the species showed extremely dissimilar (0 to 0.25). The composition of insect species in different habitats is influenced by factors such as human interference, temperature, humidity, and other environmental factors (Minor *et al*., 2017). In AM garden, the plant species were mainly pomelo trees, with some shrubs and few ground cover herbaceous plants. However, the ground cover plant species in the TM garden were stably diverse, and maintained a more reasonable height all year round. The vertical and horizontal structures of vegetation are more complex than other AM garden habitats, and the richness of plant species is high, allowing more identical insect groups to survive. Therefore, the insect similarity coefficient between the two habitats was low. Many argue that insect communities are not only susceptible to the influence of ecological factors at small scales, but also more affected by changes in ecological factors (Hendrickx *et al*., 2009; Diarra et al., 2022) at larger spatial scales due to the limited dispersal ability of insects, such as temperature, topography and geomorphology (Birkhofer *et al*., 2017). Both vegetation evolution and artificial disturbance have great impact on insect diversity, among which changes in the species structure of the vegetation zone due to artificial disturbance have a noticeable impact on insect species changes (Setzer and Vanhala, 2019). Rich variety of herbaceous plants in TM orchard provide good environment for the habitat and reproduction of various insects, which demonstrate that different habitat types dominated by vegetation had a highly significant effect on the species diversity characteristic values of insects under different management modes.

***Conclusion*:** In this study, we investigated the pest communities in orchards with different habitats under different management modes, a total of 6,043 insect specimens were collected. Overall, both orchards had a rich variety and quantity of insects. The species amount was bigger in TM orchard while the insects number was lower. The dominant insects in were orders of Diptera, Hemipter and Lepidoptera in both orchards, with a noticeable difference in population density in AM orchard while a more evenly distribution in TM orchard. It can be seen that the diversity of plants within different habitats affects the diversity and stability of insect species. The number of species and individuals in the AM orchard showed an increase over the survey period, with species reaching their peak at the end of September and then beginning to decline. The number of individuals reached its maximum at the end of August and then begins to decrease, which showed a naturally dynamic trend of community diversity. By comparison, the number of species and individuals in TM orchard showed certain fluctuations, which owed to the standardized management measures within the orchard, generating a reasonable allocation of insect populations and a comparable distribution of dominant pests, maintaining a good and stable ecological environment.

The values of *Margalef index, Shannon-wiener index, Pielou index* and *Simpson index* had significant differences between TM orchard and AM orchard (P<0.05). *Margalef index, Shannon-wiener index* and *Pielou index* in TM orchard were much higher, and *Simpson index* was smaller. The low similarity of insects between different habitats indicates significant differences in insect composition. which could illustrate the fact that a richer species of ground cover plants

in the habitat may produce a more stable ecosystem that can meet the requirements of growth and reproduction for insects. That's to say, moderate human interference not only reduces the rampant reproduction of dominant pests, maintains harmonious coexistence of populations, improves evenness, but also creates a good ground cover environment, promoting the diversity and richness of insect communities. Therefore, scientific and standardized manual management measures are particularly important in modern agricultural production. The diversity index of insect community in AM orchard was at a low level, which showed that the ground cover plant types were single, which posed a great threat to insect diversity, and was prone to pest outbreaks, so it is difficult to achieve ecological control. From another perspective, the biodiversity of TM orchard had always been rich, the ecological environment was stable, the insect community structure was reasonable, and there were no particularly advantageous pest occurrences. This also indicated that the artificial management measures of the orchard were scientific, without abuse or misuse of chemical pesticides, which should be respected and affirmed.

This study revealed the effects of different types of habitats on insect diversity under different management modes. Insect population changes in AM orchard were greatly influenced by natural factors such as temperature or the law of their growth and decline. The richness and diversity of insects in TM orchard were higher due to the diversity of plants and moderate human interference. We can explore the ecological control and comprehensive management effect of weed species purification or grass planting patterns on insect pests in pomelo orchard in the future, with a view to keep reducing chemical control and improving fruit quality.

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Conflict of interest: The authors declare no conflict of interest.

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